Challenges and solutions for waste and waste water reuse

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Content

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- Faecal sludge and sewage sludge
- Use of treated waste water
- Risk for humans and the environment
  - WHO Guidelines 2006
  - EU Guidelines USEPA guidelines for biosolids
- Risk reduction measures

Challenge

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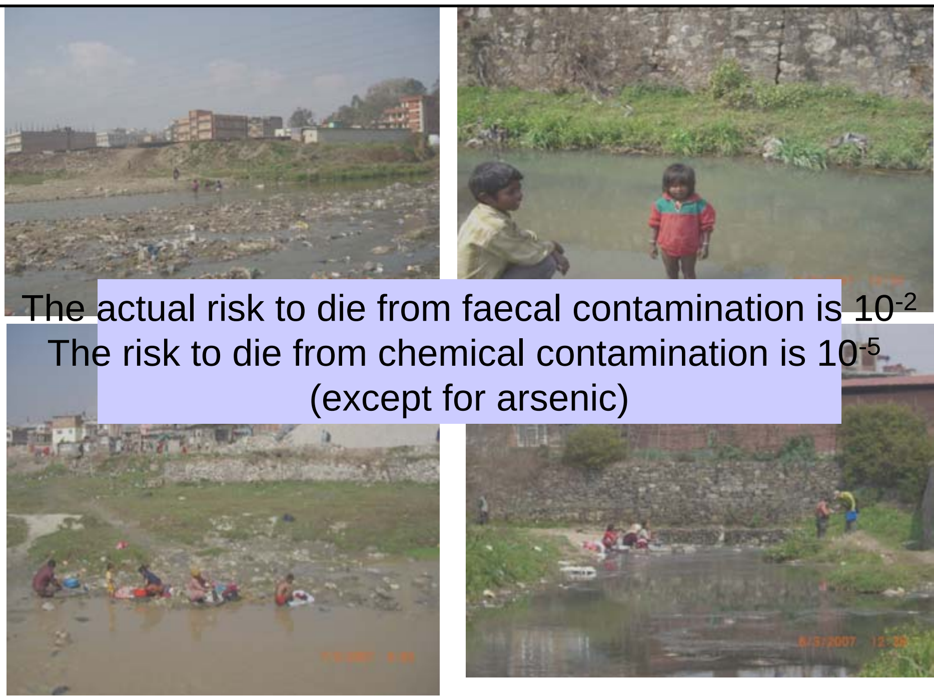
Water scarcity

- Within the next 50 years 40 % of the world´s population will live in countries facing water stress

Uncontrolled discharge of waste water

- affects the quality of natural surface water
  - presents a high risk for the population
  - and the environment



The actual risk to die from faecal contamination is 10^{-2}
The risk to die from chemical contamination is 10^{-5}
(except for arsenic)

Chance – source of nutrients

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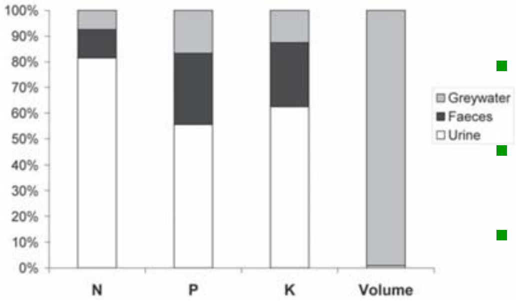

- Major plant nutrients are found in human excreta
- 13 g N, 1.5 g P, 4 g K in 150 – 200 l (e.g. in Sweden)
- Sewage sludge is rich in P, N, Ca and organic matter

Faecal sludge, sewage sludge

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WHO (2006)

Faecal sludge - Sludges of variable consistency collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies.

USEPA: Sewage sludge is the solid, semisolid, or liquid organic material that results from the treatment of domestic waste water by municipal wastewater treatment plants.

- The terms sewage sludge and biosolids are used by EPA interchangeably, but others often use the term biosolids to describe sewage sludge that has had additional processing for land application.

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Faecal sludge

Critical control points for prevention of enteric disease transmission (WHO, 2006)

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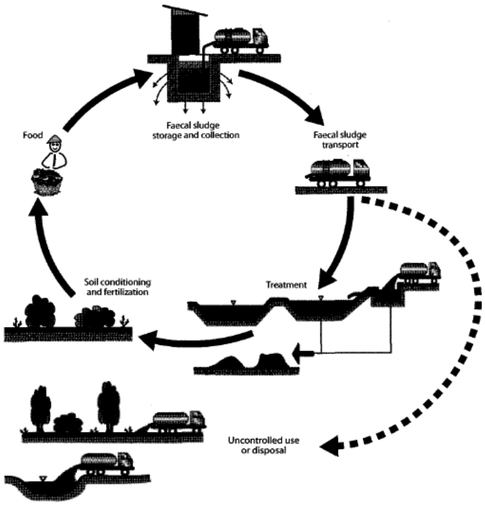

Treatments
– Digester (biogas)
– Activated sludge plants

– Drying beds
– Co-composting
– Lime

Recommendations for storage treatment of dry excreta and faecal sludge before use at the household and municipal levels (WHO, 2006)

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Treatment	Criteria	Comment
Storage; ambient temperature 2–20 °C	1.5–2 years	Will eliminate bacterial pathogens; regrowth of *E. coli* and *Salmonella* may need to be considered if rewetted; will reduce viruses and parasitic protozoa below risk levels. Some soil-borne ova may persist in low numbers.
Storage; ambient temperature >20–35 °C	>1 year	Substantial to total inactivation of viruses, bacteria and protozoa; inactivation of schistosome eggs (<1 month); inactivation of nematode (roundworm) eggs, e.g. hookworm (*Ancylostoma*/*Necator*) and whipworm (*Trichuris*); survival of a certain percentage (10–30%) of *Ascaris* eggs (≥4 months), whereas a more or less complete inactivation of *Ascaris* eggs will occur within 1 year.
Alkaline treatment	pH >9 during >6 months	If temperature >35 °C and moisture <25%, lower pH and/or wetter material will prolong the time for absolute elimination.

[a] No addition of new material.

Treatments for excrete and faecal sludge at municipal level (WHO, 2006)

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Treatment	Criteria	Comment
Alkaline treatment	pH >9 during >6 months	Temperature >35 °C and/or moisture <25%. Lower pH and/or wetter material will prolong the elimination time.
Composting	Temperature >50 °C for >1 week	Minimum requirement. Longer time needed if temperature requirement cannot be ensured.
Incineration	Fully incinerated (<10% carbon in ash)	

[a] Run in batch mode without addition of new material.

Legal and institutional aspects – faecal sludge management

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Elements necessary for a sound legal framework in urban sanitation/FSM:

- Licensing FS collection entrepreneurs and FSTP operators (contractees) by the municipality
- Establishing national legislation on FSM in general, collection and treatment requirements/product quality
- Defining the role and responsibility of each stakeholder
- Tariff system

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Sewage sludge

Centralised systems

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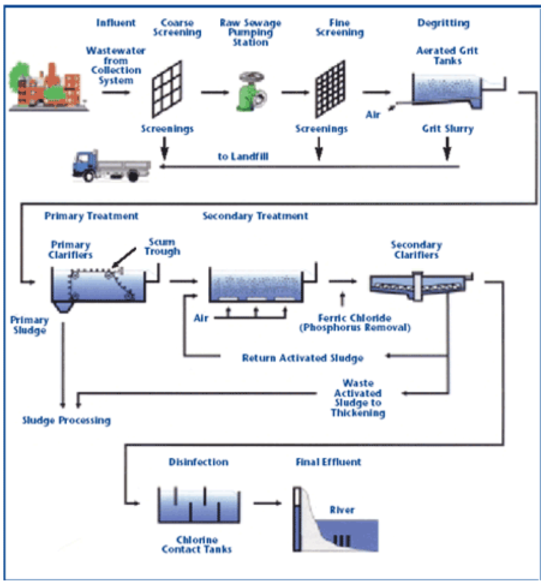

Sewage Treatment System

Biosolids from sewage sludge

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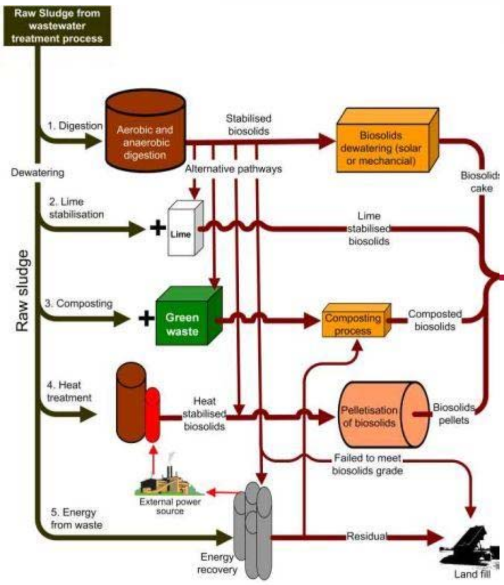

Beneficial uses
Agriculture
Landscaping
Forestry
Other products

Sludge selection – only the „best“

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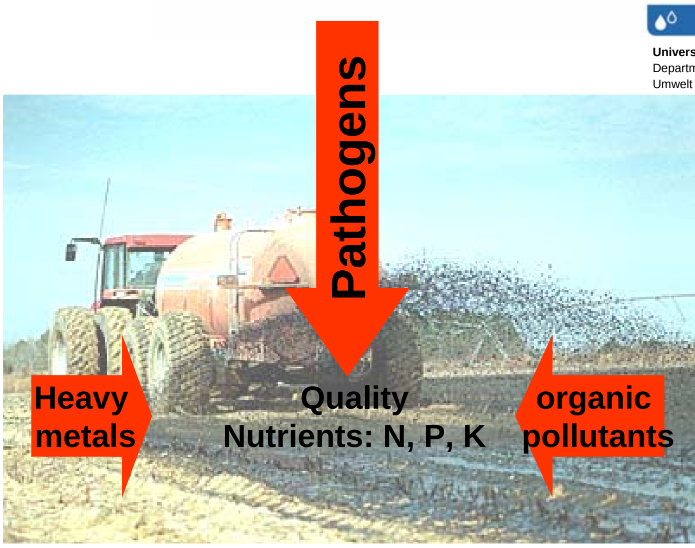

Standard setting

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Precautionary principle	Risk assessment
In face of environmental threats that are potentially devastating but unknown in scope and range of impacts	appropriate targets needs a sound database time comsuming
Political judgements needed	priorisation possible Delayed in action

In case the knowledge for RA is not available at a proper time, no action is taken,
PP acts in advance // RA is lacking behind

Risk assessment

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Scientific part

Exposure/or environmental concentration (PEC)

Effect/ or predicted no effect conc. (PNEC)

Risk characterisation
PEC/PNEC > 1

Take action

Political part

Socio economic considerati
Public perception

Exposure pathways used for risk assessment for land application (USEPA)

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1. Biosolids → Soil → Plant → Human
2. Biosolids → Soil → Plant → Human
3. Biosolids → Human
4. Biosolids → Soil → Plant → Animal → Human
5. Biosolids → Soil → Animal → Human
6. Biosolids → Soil → Plant → Animal
7. Biosolids → Soil → Animal
8. Biosolids → Soil → Plant
9. Biosolids → Soil → Soil → Organism
10. Biosolids → Soil → Soil → Organism → Soil → Organism → Predator
11. Biosolids → Soil → Airborne Dust → Human
12. Biosolids → Soil → Surface Water → Human
13. Biosolids → Soil → Air → Human
14. Biosolids → Soil → Ground Water → Human

USEPA Approach

- 1982, EPA "40 City Study" : information on the fate and effects of priority pollutants in wastewater treatment plants and estimates of pollutant concentrations in sewage sludge.
- 1988, EPA National Sewage Sludge Survey : obtain updated information on the concentration of over 400 pollutants in the Nation's sewage sludge .

→ standards for ten metals and operational standards fo

- 2001, EPA survey to obtain updated national estimates of dioxins and dioxin-like compounds

→ neither numerical standards nor additional managem practices are needed to protect human health and th

USEPA Approach

- 2003, EPAidentified a subset of 15 pollutants that needed further evaluation. EPA subsequently reduced the list of pollutants to nine—barium, beryllium, manganese, silver, fluoranthene, pyrene, 4-chloroaniline, nitrate, and nitrite
  - EPA expanded the list of analytes to reflect the Agency's interest in collecting concentration data for other chemicals:
    - barium, beryllium, manganese, and silver
    - benzo(a)pyrene
    - 2-methylnaphthalene
    - bis (2-ethylhexyl) phthalate
    - fluoride
    - water-extractable phosphorus
    - 11 polybrominated diphenyl ethers (PBDEs).
    - 97 pharmaceuticals, steroids, and hormones because of broader emerging interest in these analytes.

Maximum level of heavy metals in the EU in sewage sludge (mg/kg dm) (Gendebien, 2008)

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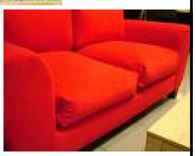
	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Directive 86/278/EEC	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000
Austria							
Lower Austria	2	50	300	2	25	100	1500
Upper Austria	10	500	500	10	100	400	2000
Burgenland	10	500	500	10	100	500	2000
Voralberg	4	300	500	4	100	150	1800
Steiermark	10	500	500	10	100	500	2000
Carinthia	2.5	100	300	2.5	80	150	1800
Belgium (Flanders)	6	250	375	5	100	300	900
Belgium (Walloon)	10	500	600	10	100	500	2000
Bulgaria	30	500	1600	16	350	800	3000
Cyprus	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000
Czech republic	5	200	500	4	100	200	2500
Denmark	0.8	100	1000	0.8	30	120	4000
Estonia	15	1200	800	16	400	900	2900
Finland	3	300	600	2	100	150	1500
France	20	1000	1000	10	200	800	3000
Germany (1)	10	900	800	8	200	900	2500
Germany (2)	2	80	(600)	1.4	60	100	(1500)
Greece	20-40	500	1000-1750	16-25	300-400	750-1200	2500-4000
Hungary	10	1000/1(3)	1000	10	200	750	2500
Ireland	20		1000	16	300	750	2500
Italy	20		1000	10	300	750	2500
Latvia	20	2000	1000	16	300	750	2500
Lithuania	-	-	-	-	-	-	-
Luxembourg	20-40	1000-1750	1000-1750	16-25	300-400	750-1200	2500-4000
Malta	5	800	800	5	200	500	2000
Netherlands	1.25	75	75	0.75	30	100	300
Poland	10	500	800	5	100	500	2500
Portugal	20	1000	1000	16	300	750	2500
Romania	10	500	500	5	100	300	2000
Slovakia	10	1000	1000	10	300	750	2500
Slovenia	0.5	40	30	0.2	30	40	100
Spain	20	1000	1000	16	300	750	2500
Spain	40	1750	1750	25	400	1200	4000
Sweden	2	100	600	2.5	50	100	800
United Kingdom	PTE regulated through limits in soil						

Risk assessment for emerging contaminants

Name	Name
NPE NonylPhenol and -NP-Ethoxylates	Organotin substances (TBT, DBT, MBT)
BPA Bisphenol A	Synthetic musk (Galaxolid, Tonalide, musk-xylol)
Brominated diphenylether (PBDE)	Perfluoro compounds
Triclosane	EE2 synthetic hormon 17a-ethinylestradiol
Short chained chorparaffines	Drugs Antibiotika
PAH, PCDD/F	Priones (mad cow disease)



Studies in Germany, Swiss and Austria, UK

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- Only persistant pollutants are of interest –potential accumulation
- Measured concentrations
  - Very low
  - Mainly (in case of organic pollutants) below LOQ
- Difference between amended soils and control was small: ratio 0.5 – 10
- Data base for polycyclic musk compounds, organo tin compounds should be improved

The mere detection of compounds ↓ does not mean that there is a risk!

In the respective studies (including the EPA) no **unacceptable risk** could be connected to organic pollutants!

Waste water reuse

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Excreated organism concentrations in WW
(WHO, 2006)

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Organism	Numbers in wastewater (per litre)
Bacteria	
Thermotolerant coliforms	10^8–10^{10}
Campylobacter jejuni	10–10^4
Salmonella spp.	1–10^5
Shigella spp.	10–10^4
Vibrio cholerae	10^2–10^5
Helminths	
Ascaris lumbricoides	1–10^3
Ancylostoma duodenale / Necator americanus	1–10^3
Trichuris trichiura	1–10^2
Schistosoma mansoni	ND
Protozoa	
Cryptosporidium parvum	1–10^4
Entamoeba histolytica	1–10^2
Giardia intestinalis	10^2–10^5
Viruses	
Enteric viruses	10^5–10^6
Rotavirus	10^2–10^5

ND, no data
Sources: Feachem et al. (1983); Mara & Silva (1986); Oragui et al. (1987); Yates & Gerba (1998).

Exposure route:
Contact/consumption

Relative importance:
Low – high

Routes of Transmission/Exposure to Pathogens or Contaminants

People at risk:
Consumers

- **Consumption of contaminated products**
- **Consumption of drinking water contaminated due to wastewater use activities**
- **Consumption of animals or animal products contaminated due to wastewater exposure**

Exposure & Burden of Disease

People at risk:
Farm workers and their families
Nearby communities

- Human contact with wastewater or contaminated crops
- Inhalation
- Vector borne disease transmission

resulting from the development and management of wastewater irrigation schemes

WHO Guideline (2006) on reuse of human excreta

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are built on...

the assessment and management of health risks associated with wastewater use through the application of various health protection measures during all steps of wastewater use and until it reaches the consumer

because...

the consumer have a right to demand safe food.

Tolerable health risk (WHO, 2004)

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Carcinogenic chemicals → Upper-bound excess risk 10^{-5}

⇔

Microbiological contaminations → Disease burden associated $1*10^{-6}$ DALY per person per year

↓

Mild but more frequent illness
e.g. self-limiting diarrhoea
(e.g. case fatality rate $1*10^{-5}$ at an annual disease risk of 1 in 1000
(1 in 10 lifetime risk)
This is also about $1*10^{-6}$ DALY pppy

How do WHO Guidelines protect people?

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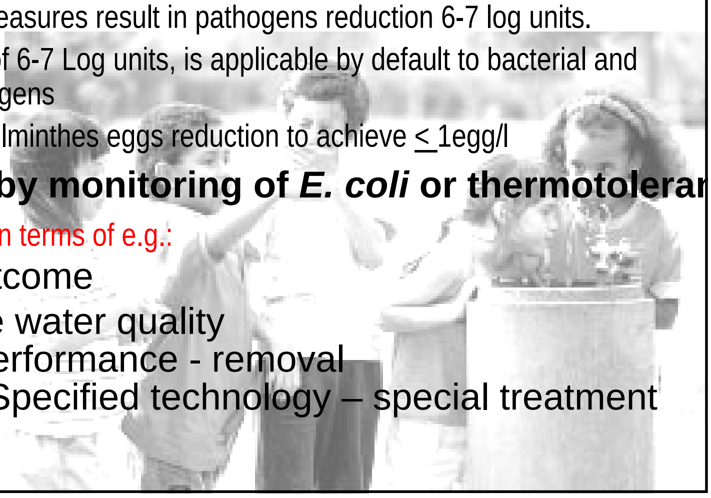
Health based target of 1 µDALY can be reached when:

- all protection measures result in pathogens reduction 6-7 log units.
- viral reduction of 6-7 Log units, is applicable by default to bacterial and protozoal pathogens
- In addition - helminthes eggs reduction to achieve ≤ 1egg/l

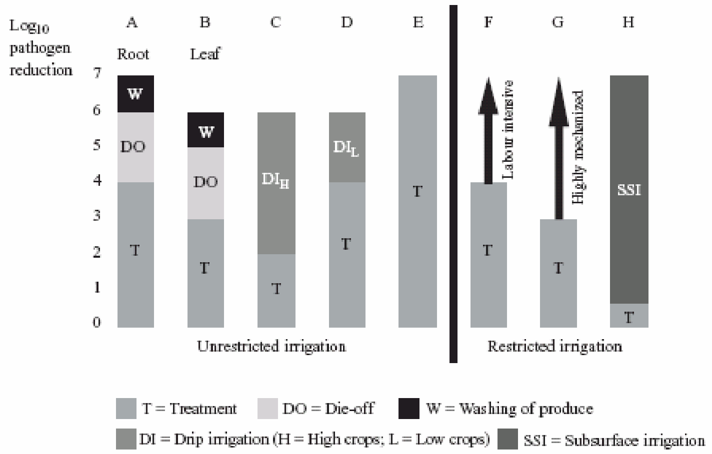


Verification by monitoring of *E. coli* or thermotoleran

Can be specified in terms of e.g.:

Health outcome
Waste water quality
Performance - removal
Specified technology – special treatment

Combination of different health protection measures to achieve the health based target of 10^{-6} DALY's per person per year



Source: WHO guidelines for safe use of wastewater, excreta and grey water, 2006

Challenge

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Faecal sludge utilisation

- Technical problem – to prevent contamination

Sewage sludge use

- No scientific question – political issue
- PR of food industry - negative public perception

Use of treated waste water

- Farmer and the food market needs to be included
- People do not like to drink their WW – a soil passage seems to be acceptable

Suggestions for solutions

nanagement should shift from water supply driven to water

Promote conservation (instead of new sources)
appropriate quality for different demands (including \

- Ensure positive public perception
- Include the farmers, the food industry and markets in the development of the reuse strategy (standard setting and monitoring)
- Provide monitoring reports to the public, farmers and industry
- Rename the product – biosolids instead of sewage sludge

Conclusions

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Wastewater or sludge use in agriculture demands:

- Proper treatment for pathogen and contaminant reduction
- Safe way of application – select crops or prohibition
- Monitoring and control strategy
- Hygiene education programs for farmers and local food handlers

to sustain and ensure

d **beneficiary use of wastewater and sludge** in agricultur

to achieve: **human and environmental health**

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Thank you for your attention

Third edition of the WHO
Guidelines for the safe use of wastewater, excreta and greywater, 2006

EPA. Biosolids
http://www.epa.gov/waterscience/biosolids/tnsss-overview.html#regulation

How can treated wastewater be reused?

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- Urban water reuse (unrestricted & restricted) (e.g. toilet flushing)
- Agricultural irrigation (food & nonfood crops) (unrestricted & restricted)
- Recreational water use (unrestricted & restricted)

- Environmental water reuse (Wetlands restoration, stream augmentation, water impoundments for boating, wading, and swimming
- Industrial water reuse (e.g. cooling water)
- Groundwater recharge
- Indirect potable reuse

Ranges for Pathogen Reduction by Various Health Protection Measures

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- Treatment — 1-6 log units
- Drip irrigation (Low growing crops, (LGC) — 2 log units
- Drip irrigation (high growing crops, (HGC) — 4 log units
- Spray irrigation — 1 log units
- Spray buffer zone — 1 log units
- Pathogen die off — 0.5-2.0 log units
- Produce Washing — 1 log units
  Produce peeling — 2 log units
- Produce cooking — 6-7 log units
- Produce disinfecting — 2 log units

Log unit reduction or inactivation of excreted pathogens by selected waste water treatment processes (WHO, 2006)

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Treatment process	Log unit pathogen removals[a]			
	Viruses	Bacteria	Protozoan (oo)cysts	Helminth eggs
Low-rate biological processes				
Waste stabilization ponds	1–4	1–6	1–4	1–3[b]
Wastewater storage and treatment reservoirs	1–4	1–6	1–4	1–3[b]
Constructed wetlands	1–2	0.5–3	0.5–2	1–3[b]
High-rate processes				
Primary treatment				
Primary sedimentation	0–1	0–1	0–1	0–<1[b]
Chemically enhanced primary treatment	1–2	1–2	1–2	1–3[b]
Anaerobic upflow sludge blanket reactors	0–1	0.5–1.5	0–1	0.5–1[b]
Secondary treatment				
Activated sludge + secondary sedimentation	0–2	1–2	0–1	1–<2[b]
Trickling filters + secondary sedimentation	0–2	1–2	0–1	1–2[c]
Aerated lagoon + settling pond	1–2	1–2	0–1	1–3[c]
Tertiary treatment				
Coagulation/flocculation	1–3	0–1	1–3	2[b]
High-rate granular or slow-rate sand filtration	1–3	0–3	0–3	1–3[b]
Dual-media filtration	1–3	0–1	1–3	2–3[b,d]
Membranes	2.5–>6	3.5–>6	>6	>3[b,d]
Disinfection				
Chlorination (free chlorine)	1–3	2–6	0–1.5	0–<1[b]
Ozonation	3–6	2–6	1–2	0–2[c]
Ultraviolet radiation	1–>3	2–>4	>3	0[c]

Helminth removal in different treatment processes for faecal sludge (WHO, 2006)

Treatment option or process	Helminth egg log reduction	Duration	Reference
Low-cost			
Faecal sludge settling ponds	3	4 months	Fernandez et al. (2004)
Faecal sludge reed drying beds (constructed wetlands)	1.5	12 months	Koottatep et al. (2004)
Drying beds for dewatering (pretreatment)	0.5	0.3–0.6 months	Heinss, Larmie & Strauss (1998)
Composting (windrow thermophilic)	1.5–2.0	3 months	Koné et al. (2004)
pH elevation >9	3	6 months	Chien et al. (2001)
Anaerobic (mesophilic)	0.5	0.5–1.0 month	Feachem et al. (1983); Gantzer et al. (2001)
High-cost			
pH elevation >12	3		Gantzer et al. (2001)
Thermophilic, in-vessel (aerobic/anaerobic)	3	1–5 days	Haug (1993); Eller, Norin & Stenström (1996)

Maximum concentrations of organic contaminants in sewage sludge (mg kg-1 dm except PCDD/F: ng TEQ kg-1 DS) (Gendebien, 2008)

	Absorbable organic halides (AOX)	Bis(2-ethylhexyl) phthalate (DEHP)	Linear Alkylbenzene Sulfonate (LAS)	Nonylphenol/ Nonylphenol ethoxylate (NP/NPE)	Polycyclic aromatic hydrocarbon (PAH)	Polychlorinated biphenyls (PCB)	Dioxins/Furans (PCDD/F)	others
Directive 86/278/EEC	-	-	-	-	-	-	-	
EC (2000)a)	500	100	2600	50	6b	0.8c	100	
EC (2003)a)			5000	450	6b	0.8c	100	
Austria								
Lower Austria	500	-	-	-	-	0.2 d)	100	
Upper Austria	500					0.2 d)	100	
Vorarlberg	-					0.2 d)	100	
Carinthia	500				6	1	50	
Denmark (2002)		50	1300	10	3b			
France					Fluoranthene: 4 Benzo(b)fluoranthene: 2.5 Benzo(a)pyrene: 1.5	0.8c)		
Germany (BMU 2002)	500					0.2 e)	100	
Germany (BMU 2007) f)	400				Benzo(a)pyrene: 1	0.1 e)	30	MBT+OBT:0.6 Tonalid: 15 Glalaxolide:10
Sweden	-	-	-	50	3b)	0.4c)	-	
Czech Republic	500					0.6		

a proposed but withdrawn
b sum of 9 congeners: acenapthene, fluorene, phenanthrene, fluoranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-c,d)pyrene
c sum of 7 congeners: PCB 28, 52, 101, 118, 138, 153, 180
d sum of 6 congeners:PCB28,52,101,138,153,180
e Per congener
f Proposed new limits in Germany (BMU 2007)

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Emerging contaminations

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- Musk fragrances (tonalide and glalaxolide)
- PFOS
- Nanoparticles
- Priones (mad cow disease)

Sludge treatment for pathogen reduction

Current	Proven new processes or variants being used to replace or supplement existing processes	Novel
MAD – Mesophilic anaerobic digestion TD – Thermal destruction (normally now with energy recovery) Lime addition for stabilisation or pasteurisation Compost Aerobic or Thermophilic aerobic digestion Landfill Drying	THP – Thermal Hydrolysis Process APD – Acid phase digestion processes Co-digestion or co-composting with non-sludge organic materials Wet oxidation (after digestion)	Pyrolysis Gasification (Both of the above already exist but few installations) TD with P recovery

The strategies should be developed under a HACCP approach